Considerations Related to Planning for the Exploration of the Martian Subsurface

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Jet Propulsion Laboratory
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Goddard Space Flight Center

Johnson Space Center

Ames Research Center

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HONEYBEE ROBOTICS

Schlumberger

Participants from

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California Institute of Technology
Caltech
Goddard Space Flight Center
NASA Astrobiology Institute
Johnson Space Center
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"There is a need to chemically characterize, map, and ground-truth subsurface volatiles, focusing on H_2O, and the overburden over multiple spatial scales, from meters to multiple km, as it applies to the search for life and resources."

The goal of this workshop is to meet this need by identifying scientific measurements, instruments, & technologies, as well as mission concepts & strategies.

Outline

- Why Mars, why subsurface, why start now?
  - *Science with depth*
  - *New 3D science*
  - *Human & commercial opportunities*
  - *New technologies to access the underground*
- Missions with depth
  - *From questions to missions*
  - *Drilling from mm to miles*
  - *EM sounding for liquid water*

Why Mars, why subsurface, why start now?

Science with depth

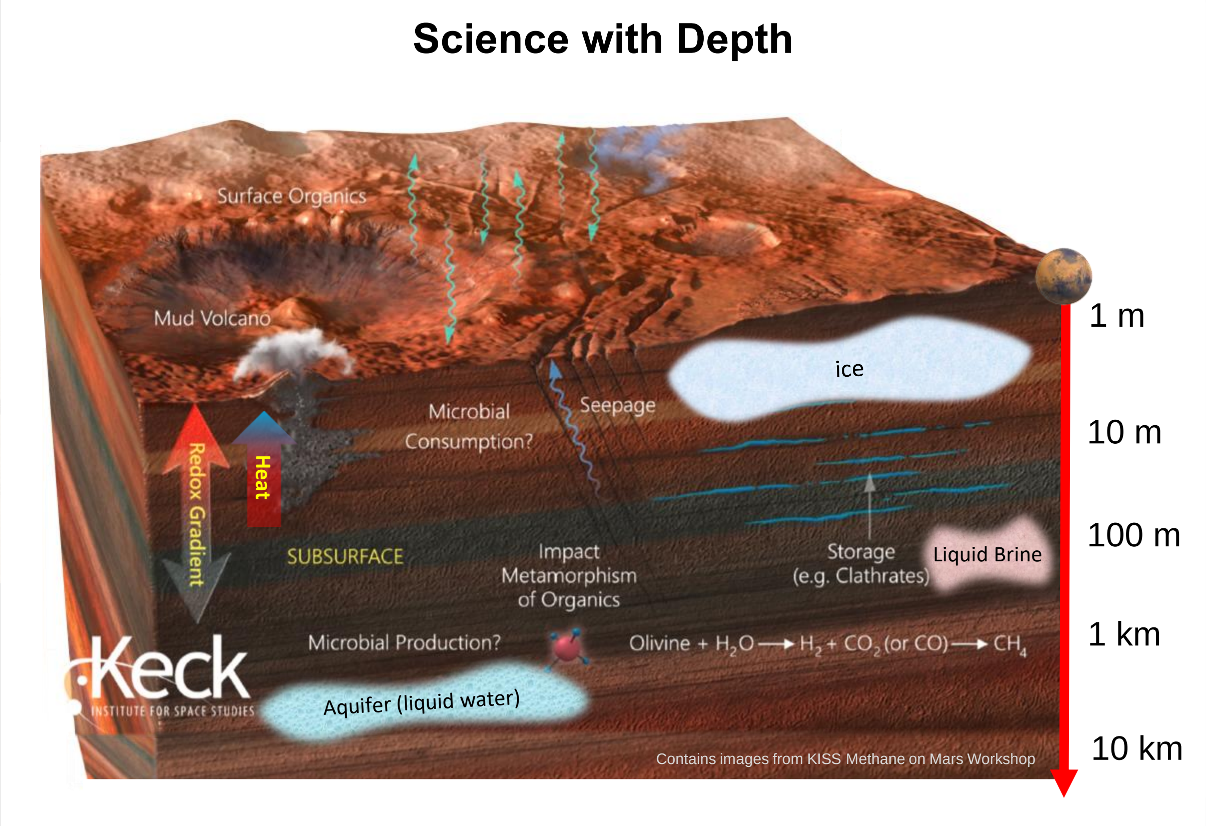
For Life, Water, Resources & Climate

- **If we are looking for life and water, then there is no better place than the Martian subsurface.**

➢ **Extinct life:** longest living habitat. At greater depth (>1-5m) the likelihood of biosignature preservation is greater due to shielding from radiation.

➢ **Extant life:** If life still exists on Mars, then it is most likely to be found where liquid water exists. Brines could be liquid at shallower depth. Spectral evidence suggests brines on or close to the surface. Pure water aquifers are more likely to be below 1-10 km.

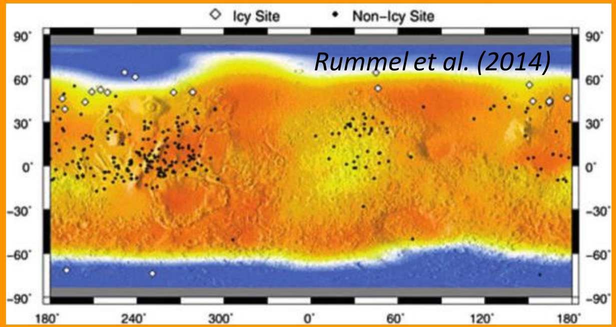
- **Follow & find the water**
- **Climate & planet evolution:** volatiles & drill cores



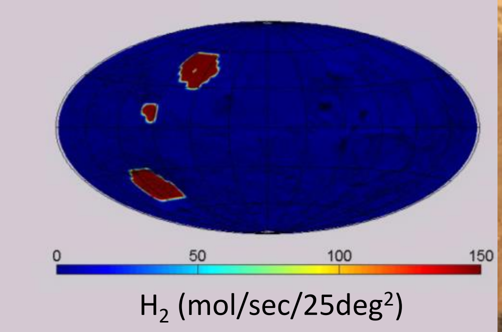
New 3D science

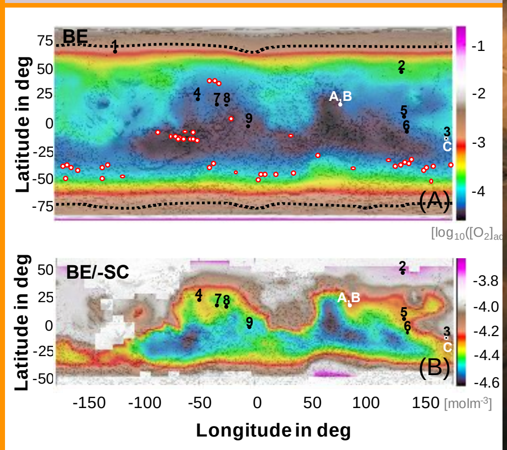
RSL

ICE/WATER

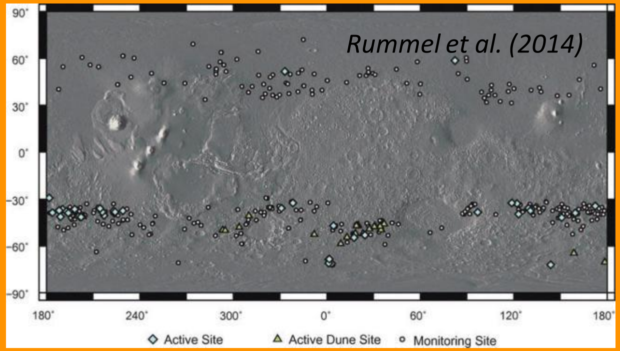


REDOX GRADIENTS

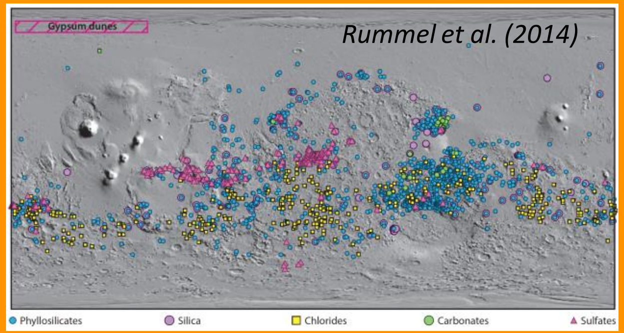




ACTIVE GULLIES



MINERALOGY



Life from inside out

Connecting Geodynamics to Life

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Human & commercial opportunities

- NASA’s planning of sending humans to Mars beyond the 2030s calls for mapping of Martian subsurface resources (e.g., water, methane, oxidants, clathrates) and human hazards, and the exploration of the only potential modern-day habitat which is the Deep Subsurface.
- Commercial collaboration opportunities through, e.g., SpaceX who could provide flights to Mars every 2 years, possibly as early as 2022.
- Growing international interest in Mars exploration with Emirates, India, China, and Japan joining NASA and ESA in Mars exploration in the early 2020s.

New technologies to access the underground

Drilling/In Situ Analysis

- MEMS & Miniaturization of instruments
- Increase in processors computational speeds
- Drilling automation
- Instruments can be brought to the samples
- Sensor-driven on the fly efficiency adaptation
- Low-power Logging While Drilling (LWD)
- Measurement-While Drilling (MWD)
- Instrumented Drillbits (for CH_4 & H_2O)
- AutoGopher Rotary-Ultrasonics
- Foro-type borehole lasers
- Wire line/Inchworm approaches
- CoiledTubing
- Pneumatic based excavation
- EM Hammer mole (hammering inside)
- CRUX Drill w. Neutron spectrometer
- Down Hole Magnetometry
- Redox Electrodes
- SmallSat penetrators
- BFR Penetrator/Drill
- **And many more…**

Sounding

- Flux chambers as in terrestrial seepage detection
- SNMR (e.g., Schlumberger CMR/MRX)
- MEMS, Miniaturization of instruments (e.g., seismometers)
- Increase in processor computational speeds
- SmallSats for outgassing monitoring such as GHGSats
- SmallSat bistatic radar air/ground (RAX/RainCube Combos)
- CubeSats enable low-frequency sounding
- CubeSats telecom and data processing enhancements
- CubeSats agile science operations
- **And many more…**

Why Mars, why subsurface, why start now?

We are ready to start exploring the Martian subsurface now: from sounding to drilling

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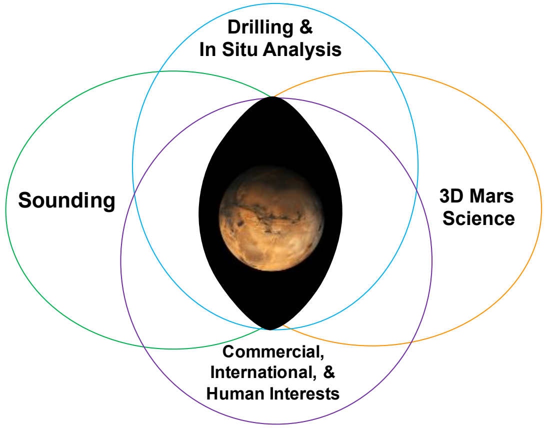
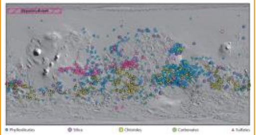


3. Commercial, International, and Human Opportunities

- Commercial collaboration opportunities through, e.g., SpaceX who aim to provide flights to Mars every 2 years, possibly as early as 2022.
- Growing international interest in Mars exploration with Emirates, India, China, and Japan joining NASA and ESA in Mars exploration in the early 2020s.
- NASA's aim to send humans to Mars beyond the 2030s calls for mapping of Martian subsurface resources (e.g., water, methane, oxidants, clathrates) and human hazards, and the exploration of the only potential modern-day habitat which is the Deep Subsurface.

2. New Science

MINERALOGY



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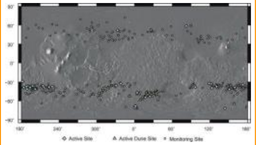
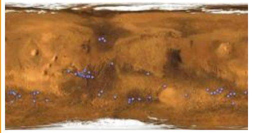
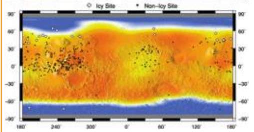


RSL



ICE/WATER



All 4 images from Rummel et al. (2014)

Life from inside out
Connecting Geodynamics to Life

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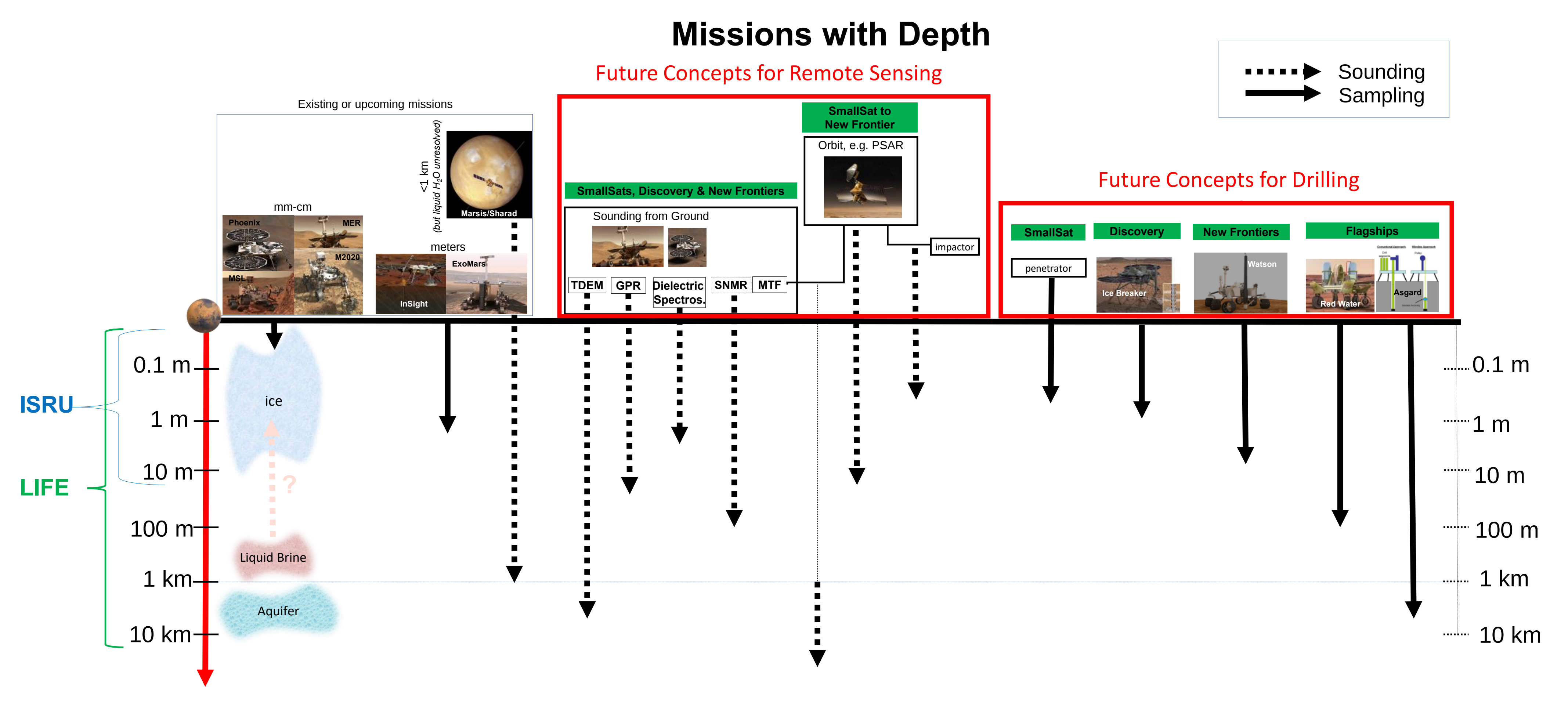
Missions with depth

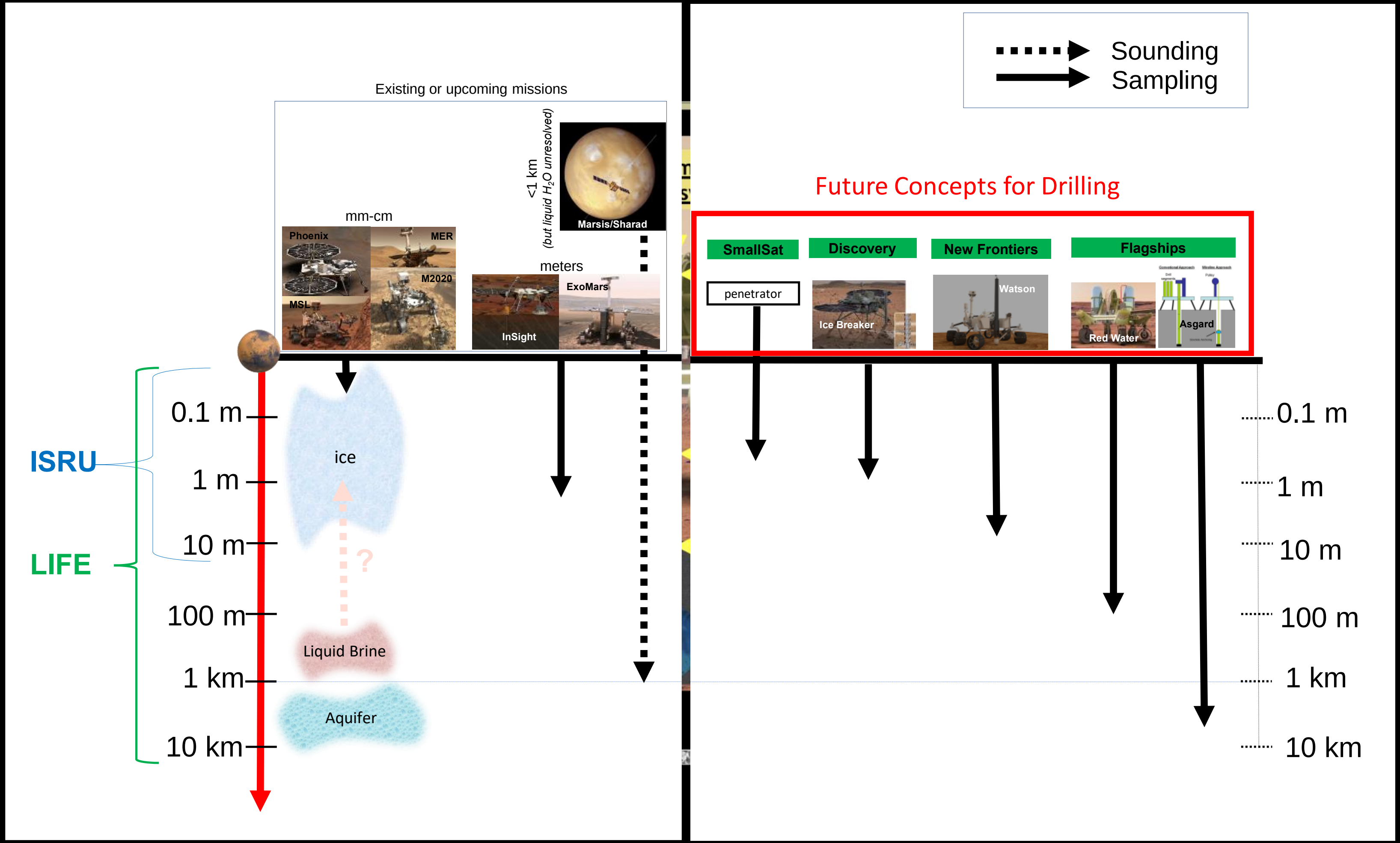
From questions to missions

Resources Science questions and necessary instrumentation				tiny: <$20M, small: $20-50M, medium: $50-150M, large: >$150M	
	Questions	**Instrument to get info**	**Lander, Orbital, Deep?**	**Instrument cost**	**Notes**
Geological Context	What is the bottom extent of the ice to within 10 m resolution, with bottom extent from 10 and 500m?	Data already existing, but some ambiguous interpretation	In a database :)	Free!	
	Where is Ice within top 5 m and 0 to 50 latitude?	Top 1 m from G/NS	In a database :) (at v. low res)	Free!	
		Impactor (not really global mapping)	~orbital	tiny	
		PSAR (yes ice, w/ large error bar; some min ice thickness req'd)	Orbital	medium	
	what is the ice vs non-ice (rock, regolith) fraction? (e.g., ice-cemented ground, burried glacier, ice lenses) Does this vary with depth, top 5m of ice, at a resolution of 0.5m and 5% by vol?	Impactors (not really global mapping, spectroscopic obs from orbit - what accuracy?)	~orbital	tiny	
		Penetrators (not really global mapping)	~orbital	small	
		Drilling (10m drill class; local only; only way to get good data to meet these req'ts?)	surface	medium	
	What is the vertical distribution of ice at 0.5m vertical resolution to 10m - for the top ice limit?	Sounder (to get necessary resolution; choose right freq)	Orbital	small	
		EM (local info only)	Surface	small	
	Information about ice overlying material to 5m: stratigraphy, density, porosity, rock distribution/content as relevant to building the removal buldoser?	Density, rock distribution - thermal IR (next gen THEMIS)	Orbital. Low lateral res - in database.	small-medium	
		GPR, seismic, EM (1 to 3 of them)	surface, roving	small-medium (each)	
		Drill (5m class) + scoop (local only)	surface	medium	
	Location and lateral extent of water resources with ~200m resolution	PSAR + Sounder (choose right freq)	Orbital (don't need to go to surf)	medium	
Overlapping Major goals	Chemical characterization of the ice in 3D to 10m (e.g., salts)?	Impactor (orbital spec observation) - is it realistic to (1) reach the ice, (2) get spectral signature from orbit of the impurity?	~orbital	tiny	
		Penetrator (with sci package in it, it embeds in ice and looks out a window)	orbital/surface	small	
		Drilling (10m class), scooping with a science package	surface	medium (+?)	Similar measuremets to life search?
Details of using resource	surface bearing strength as it relates to utilizing the resource	Cone penetrometer	Surface	tiny	
		Bevameter (shear strength; also info on drilling specs)	Surface	tiny	
	Within the 200 m resolution of where we landed, what is the 'best' location for subsequent mining?	EM	surface, mobility (roving, drone, etc)	small	
		GPR	surface or airborne, mobility (roving, drone,	small	
		seismic	surface, mobility (roving, drone, etc)	medium	
	organics and inorganics characterization for human health hazard assessment	drill & scoop	surface, mobility (roving, drone, etc)	medium	

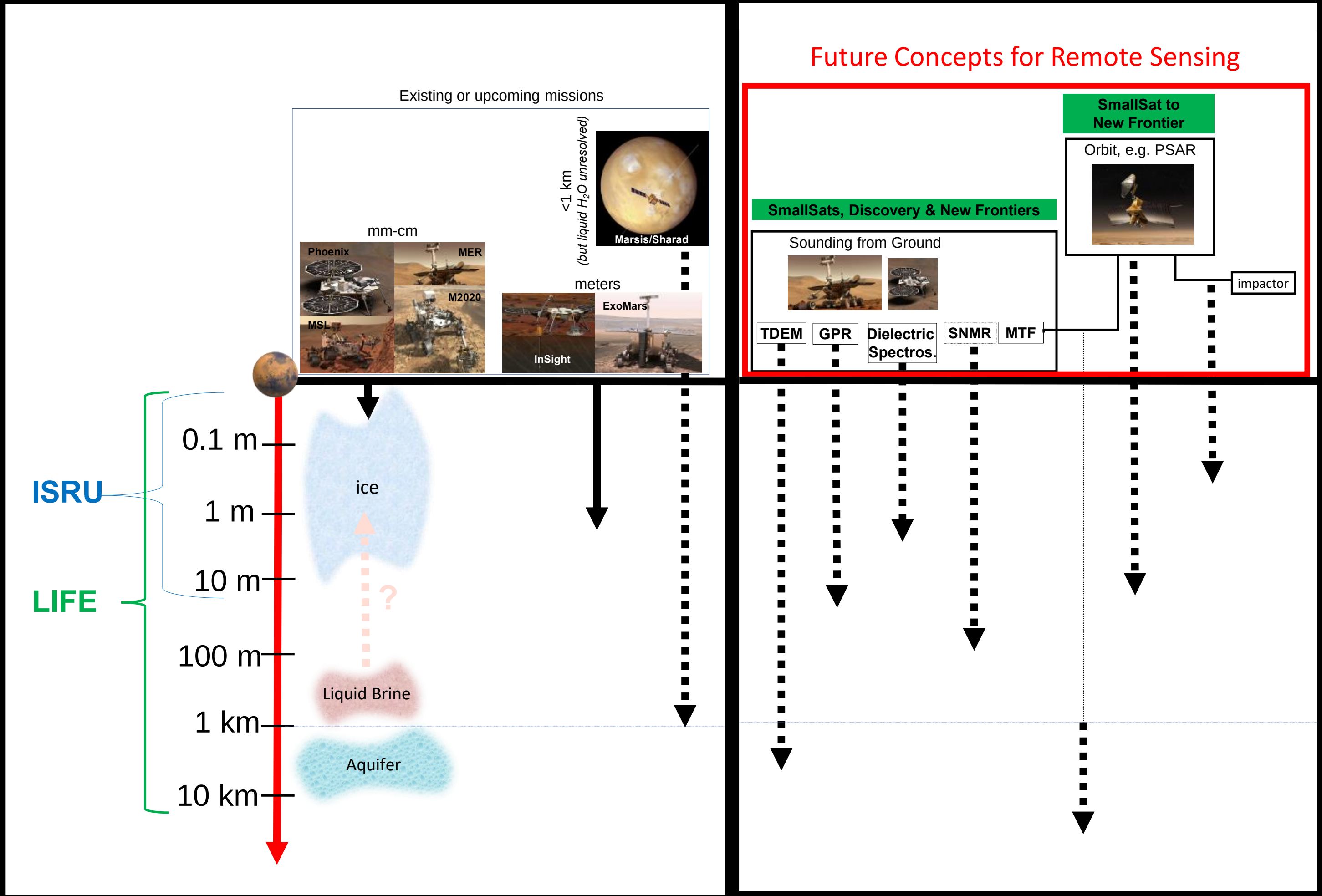
From questions to missions



Drilling from mm to miles

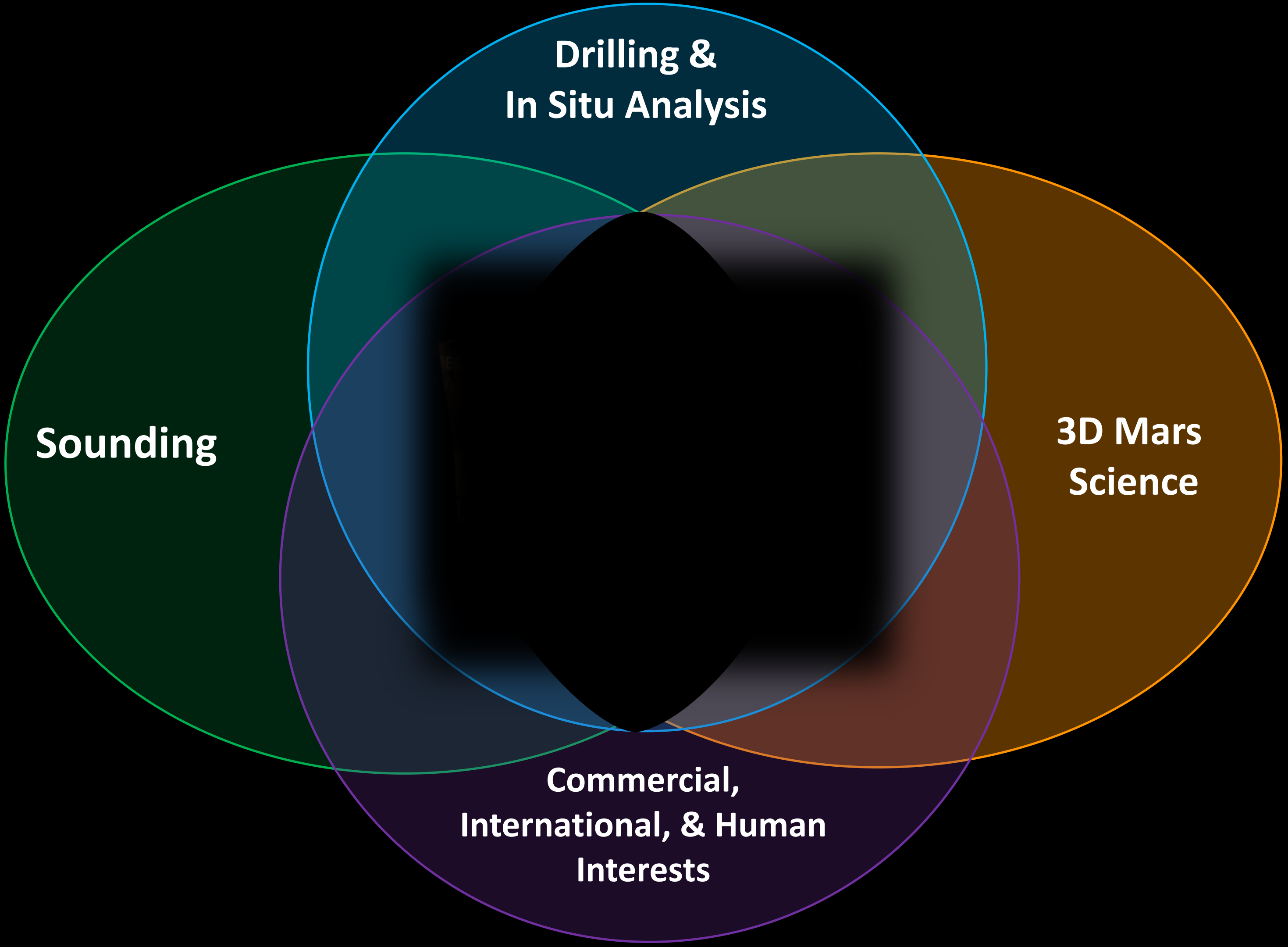


EM sounding for liquid water



In summary

- ***The quest for life (extinct and extant), water, & resources leads inevitably into Mars' underground.***
- We have not yet explored this alien dimension at all.
- 3D Mars science has evolved enough to start informing us about subsurface diversity.
- Drilling & sounding technologies are mature enough and should be explored in parallel as they are complementary.
- Human exploration and commercial worlds can help achieve these goals.



More info

- Astrobiology Decadal White Paper is out.
- KISS marsX workshop paper in Nature Astronomy and report out soon.
- AGU Session “New Mars Underground” submitted.
- Write me... *“Vlada.Stamenkovic@jpl.nasa.gov”*

Mars Subsurface Access: From Sounding to Drilling

A White Paper Submitted to The National Academies of Sciences, Engineering and Medicine's Astrobiology Science Strategy for the Search for Life in the Universe Meeting January 2018

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